Modified High Gain APDs for Multi-beam Ladar Instrumentation

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Project Summary

As more sophisticated systems for light detection and ranging (Lidar) are developed, there is a need for improved optical detectors that operate with low noise, high response and fast speeds from the ultraviolet (UV) to the near-infrared (near-IR). Avalanche photodiodes (APDs) are of particular interest for such systems because of their solid-state construction with internal gain, large bandwidth, and excellent responsivity to visible and near-IR signals. Because of this, Radiation Monitoring Devices, Inc. (RMD) has been developing a silicon-based, low noise, high gain, APD and APD arrays sensors for several decades. The advances that RMD has made in APD detector technology has always been on the forefront of innovation, promoting new scientific and engineering discoveries. Unfortunately, the optimized performance of RMD's and other commercially available APD detectors is not always an ideal match to many desirable transmitters. In particular, higher responsivity and bandwidth at UV and near-IR wavelengths is needed to match the output from Nd:YAG lasers, which typically have a fundamental wavelength of 1064 nm, along with its commonly used harmonics at 266 nm, 355 nm, and 532 nm.

The focus of this SBIR project is on the investigation and refinement of a modified fabrication technique to enhance the performance of the APDs manufactured at RMD. The method uses well-established silicon processing technology to form a uniform surface layer with the appropriate thickness and charge doping profile. Using this technique, along with our well established processing method to form large area APDs with the lowest noise and highest gains available, we expect to produce detectors that have improved response to blue-UV light along with an increase in detection bandwidth. If successful, this new detector format will become part of our solid-state product portfolio for mission-critical systems, including rugged and space-ready alternatives to photomultiplier tubes (PMTs). This would be significant for both the detection of blue-UV as well as for detection of longer wavelength photons where APDs already offer superior performance.

Through NASA SBIR funding, during our Phase I studies we were able to successfully produce working APDs with a range of doping concentrations at the near surface layer. This range of concentrations allowed us to make comparison studies and learn how the modified treatment affects the APD performance, providing a guide to further improvements. Highlights of our study include:

- Detectors with an active area of 1 cm^2 were produced with high reliability, demonstrating that we are able to minimize localized defects and increase produce yield. By introducing improved handling procedures, the yield of working detectors has approached 70%, leading to the promise that array structures can be manufactured with a complete suite of working pixels.
- The new detectors achieved a rise times of approximately 1 ns and bandwidths of > 300 MHz, which was an order of magnitude faster than our standard detectors. This resulted in very high peak signals when compared to other commercially available detectors of similar size.
- Measurements showed that the modified detectors had quantum efficiency (QE) as high as 35% in the UV without an anti-reflection coating and up to 90% in the red when a coating was applied. This represents the highest response measured to date for RMD's high gain APD detectors.

Results from the Phase I work definitively demonstrated that the proposed fabrication technique can be used to achieve improved APD detector performance in the UV through the near-IR. When augmented with our established planar processing sequence, the process will allow us to engineer an array of detectors that have optimal response tailored for a wide-range of target wavelengths. The positive result of this effort has defined a path for the further development necessary to produce commercially-ready solid state detectors with superior response at UV, visible and near-IR wavelengths. This further development has great potential to provide receivers to meet the requirements of NASA's Lidar-based science missions.